



UNIT 1 - ENERGY

SECTION 1 - ENERGEIA



CONSERVATION OF ENERGY

Background Information

Recall that energy is defined as the ability to do work. Work is done when energy is transferred from one system to another, for instance, when a force is applied to an object.

Energy may be either potential or kinetic. Potential energy (PE) is energy stored and ready for use. A car stopped at the top of a hill and a water balloon dangling out of an upstairs window have potential energy. Potential energy is measured by the amount of work the object can perform. In the case of the car or the water balloon, PE is calculated by multiplying the mass of the object (in kilograms) by the acceleration of gravity (9.8 m/sec^2) by the height of the hill or the window (in meters). Potential energy is expressed in joules (J). $1 \text{ J} = 1 \text{ kg}\cdot\text{m}^2 / \text{sec}^2$

The other form of energy is kinetic energy (KE). Kinetic energy is the energy of motion. A car rolling downhill and a water balloon falling towards its target have kinetic energy. For such objects KE is calculated by multiplying $1/2$ the object's mass (in kilograms) by the square of its velocity (m/sec^2).

Because of its greater mass, a falling car has more kinetic energy than a falling water balloon. Similarly, because of its greater velocity, a water balloon that is thrown down will have more kinetic energy than one that is simply dropped from the same height. In fact, since kinetic energy increases with the square of the velocity, a thrown water balloon that is falling twice as fast as a dropped balloon will have four times as much KE ($2^2 = 4$).

AS these examples show, potential energy can become kinetic energy. Kinetic energy can also be transferred from one object to another: imagine a car or the water balloon striking a ping-pong ball and sending it flying.

Recall also that kinetic energy comes in six forms - chemical, electrical, radiant, mechanical, nuclear, and thermal- and that each of these forms can be converted into any of the other forms. For example, a battery converts chemical energy into electricity, and a light bulb converts electricity into light and heat.

Not all energy conversions are as simple as turning on a light bulb. A power plant that uses coal to generate electricity for your home is a complex system that converts the chemical energy in coal into thermal energy, mechanical energy, and then electrical energy.

**CONSERVATION OF ENERGY
INVESTIGATION CONT.****The Law of Conservation of Energy**

Energy cannot be created or destroyed, but it can be converted and transferred. When potential energy is converted into any of the six forms of kinetic energy, the total energy in the system before the conversion equals the total energy after conversion: $PE + KE = PE + KE$. This is the Law of Conservation of Energy.

Since no energy is lost during the transfer, we can calculate the increase in kinetic energy by finding the decrease in potential energy, and vice versa.

How much kinetic energy is gained by a 3 kg ball dropped from a height of 2 meters? The answer is an amount equal to the potential energy lost:

$$\frac{1}{2} mv^2 = \text{mass of the object (m)} \times \text{acceleration of gravity (g)} \times \text{height (h)}$$

$$\frac{1}{2} mv^2 = 3 \text{ kg} \times 9.82 \text{ m/sec}^2 \times 2 \text{ m}$$

$$\frac{1}{2} mv^2 = 58.9 \text{ kg} \cdot \text{m}^2 / \text{sec}^2 = 58.9 \text{ J}$$

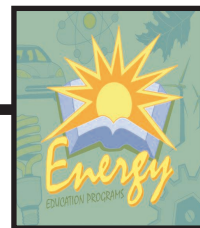
Investigation

An experiment by Galileo Galilei (1564-1642) illustrates how friction enters into this equation. Galileo set up a shallow U-shaped track that was elevated at both ends and low in the middle. He released a series of balls from one end of the track and watched them roll down, up the other side, and back again. Galileo observed that as the surfaces of the track and ball would roll back up the track farther toward its initial point of release. He concluded that the energy, which was apparently lost, was due to friction, and if friction were zero, the ball would roll back and forth endlessly.

Galileo's experiment illustrates the Law of Conservation of Energy: that the total energy in a system equal the sum of its potential and kinetic energy. In this investigation you will build on Galileo's experiment by rolling marbles down a track and a ramp, predicting where they will land, and calculating how much energy was converted to heat by friction in the system.

Problem: *(fill in problem):* _____

Hypothesis: *(fill in hypothesis):* _____



CONSERVATION OF ENERGY INVESTIGATION CONT.

Materials

marble

1 6-ft length of pipe cut in half lengthwise (foam pipe insulation is flexible, but increases friction)

meter stick

calculator

stopwatch

tape

triple beam balance

chalk

empty coffee can

Procedure

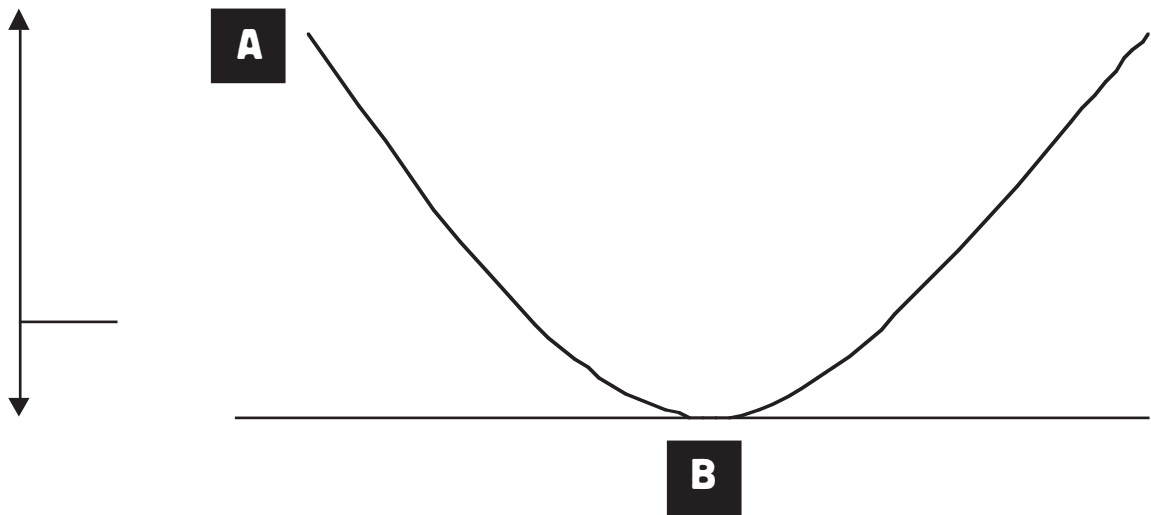
1. Measure the length of foam pipe insulation and mark the halfway point with chalk.
2. Using the pipe insulation and tape, set up a track of top of a desk as shown in diagram 1.
Make sure the area marked B on the diagram is the only part of the track touching the table.
3. Measure the distance from point A to point B. Record this distance on diagram 1.
4. Measure and record the distance from point A to the tabletop.
5. Find the mass of the marble in kilograms. Record the mass on diagram 1.
6. Using the stopwatch, measure how long it takes for the marble to roll from point A to point B. Record the time on diagram 1.
7. Calculate the average velocity of the marble from point A to point B. Record on diagram 1.
8. Calculate the potential energy of the marble at the starting point. Record on diagram 1.
9. Calculate the kinetic energy of the marble at point B.
10. Release the marble at point A and observe how far up the opposite side the marble travels.
Mark the distance the marble travels with chalk on the foam pipe insulation.
11. Measure the height from the tabletop to the greatest height the marble travels.
12. Calculate the potential energy of the marble when it has reached its greatest height. Record this value on diagram 1.
13. Calculate the energy loss due to friction. Record on diagram 1.
14. Remove the tape from one side of the track and lay it flat along the table with the end slightly overhanging the table, as shown in diagram 2.
15. Measure the height from the floor to the hanging end of the insulation. Record this distance on diagram 2.
16. Using the stopwatch, measure the time it takes for the marble to travel from point A to point

CONSERVATION OF ENERGY INVESTIGATION CONT.

- C (see diagram 2). Record the time on diagram 2. Have a partner catch the marble in the can when it comes off the track.
17. Predict where the marble will land, using the formula given in diagram 2.
 18. Place an empty coffee can on the floor at the predicted landing point. Place the marble at point A and release.
 19. Observe the trajectory of the marble as it leaves the table.

Observations

Diagram 1



Distance from A to B = _____

KE at B = $\frac{1}{2} mv^2 =$ _____

Height from table top to A = _____

Height from table top to highest point marble rolls past B = _____

Mass of marble = _____

PE of marble at highest point past B = _____

Time marble takes to go from A to B = _____

Velocity = $d/t =$ _____

Energy lost to friction = $PE_1 - PE_2 =$ _____

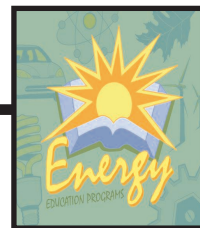
PE at A = $mgh =$ _____

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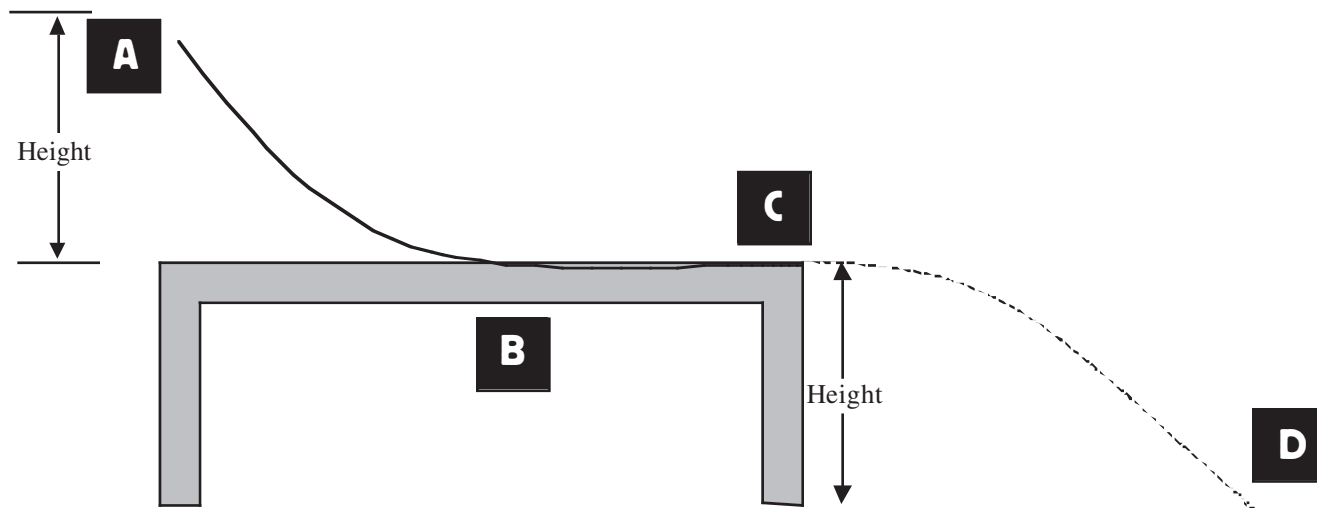
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CONSERVATION OF ENERGY INVESTIGATION CONT.

Diagram 2



Predict where the marble will land $D = \sqrt{2h/g} =$ _____

Was your prediction correct: _____ Why or why not? _____

If the marble doesn't land in the can, consider energy lost due to friction on diagram 1 and make a new prediction. Explain how you arrived at your new prediction.

**CONSERVATION OF ENERGY
INVESTIGATION CONT.****Conclusion**

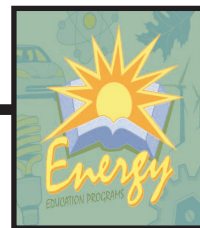
1. Neglecting friction, what is the total mechanical energy of the marble as it moves along the track? _____.
2. What happens to the marble's potential and kinetic energy as it moves up and down each incline? _____.
3. What would be the effect of increasing the angle of the ramp? _____.
4. What would be the effect of increasing the mass of the marble? _____.
5. How does the potential energy at point A compare to the kinetic energy at points B and C? _____.
6. How does this investigation illustrate the Law of Conservation of Energy? _____.

Application

1. A skydiver whose mass is 70 kg jumps out of a plane at a height of 7,000 meters. What is his potential energy as he prepares to jump?

2. A 1 kg stone is skipped across a river from a height of 0.9 m. How much kinetic energy does it gain as it falls? _____

3. A bowling ball has a mass of 5 kg and is released at a velocity of 2 m/sec to travel down a 60 ft lane. Calculate the kinetic and potential energy of the ball as it leaves the bowler's _____ hand 18 cm above the lane. Disregarding losses due to friction, sound, etc., calculate the _____ total energy of the ball at the end of the lane. _____



CONSERVATION OF ENERGY INVESTIGATION CONT.

Going Further

Extend the track by attaching another piece of foam tubing to the horizontal track. Shape the additional tubing so that it reflects the trajectory the marble took as it left the tabletop.

1. If your track represented the beginning of a roller coaster track, predict where the next rise should begin. _____

2. Predict how high the marble's release point needs to be to achieve maximum acceleration without leaving the track. Hints: (1) The maximum angle should be between 35° and 55° . (2) The first hill on a roller coaster is always taller than the second. _____

Now you are ready to test your modified track and compare results with other students. First, using the stopwatch, time how long it takes the marble to go the distance of the new track. If your marble goes airborne, your group is disqualified!

3. Draw and label the new section of your track on diagram 2. Include the velocity, kinetic energy at D, and height of the new section.
4. How does the potential energy at A compare to the kinetic energy at D? _____

5. Why does the second hill on the track need to be lower than the first hill? _____
